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A THEORY OF FORMATION OF FALLOUT FROM LAND-SURFACE  
NUCLEAR DETONATIONS AND DECAY OF THE FISSION PRODUCTS

Research and Development Technical Report USNRDL-TR-425

27 May 1960

by

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SAN FRANCISCO 24 CALIFORNIA

TABLE 5  
Fractional Chain Yields for Mass 89 for U<sup>235</sup> Fission

t (sec)	Present					Glendenin				
	Se	Br	Kr	Rb	Sr	Se	Br	Kr	Rb	Sr
0	0.05	0.372	0.528	0.100	0	0.170	0.420	0.343	0.067	0
1		0.325	0.571	0.104	0	0.121	0.410	0.399	0.070	0
2		0.280	0.612	0.108	0	0.087	0.390	0.452	0.071	0
3		0.245	0.644	0.111	0	0.062	0.362	0.502	0.074	0
4		0.212	0.673	0.115	0	0.044	0.332	0.547	0.077	0
6		0.159	0.720	0.121	0	0.022	0.266	0.629	0.083	0
9		0.102	0.764	0.133	0.0014	0.008	0.182	0.720	0.090	0
13		0.056	0.794	0.147	0.0021	0.002	0.106	0.786	0.105	0.0012
19		0.022	0.809	0.166	0.0030		0.044	0.830	0.124	0.0020
28		0.0054	0.798	0.195	0.0043		0.011	0.832	0.155	0.0032
41			0.764	0.232	0.0064		0.002	0.800	0.192	0.0050
60			0.707	0.283	0.0097			0.744	0.249	0.0076
88			0.638	0.347	0.015			0.670	0.318	0.012
129			0.564	0.436	0.025			0.559	0.419	0.022
189			0.433	0.520	0.047			0.456	0.500	0.044

TABLE 6

Fractional Chain Yields for Mass 140 for  $U^{235}$  Fission

t (sec)	Present				Glendenin					
	I	Xe	Cs	Ba	La	I	Xe	Cs	Ba	La
0	0.074	0.493	0.399	0.034	0	0.138	0.408	0.366	0.088	0
1	0.047	0.498	0.416	0.039	0	0.087	0.441	0.380	0.092	0
2	0.029	0.495	0.433	0.043	0	0.055	0.453	0.395	0.097	0
3	0.019	0.485	0.449	0.048	0	0.034	0.454	0.412	0.100	0
4	0.012	0.470	0.466	0.052	0	0.022	0.447	0.426	0.105	0
6	0.005	0.438	0.493	0.064	0	0.009	0.423	0.453	0.115	0
9	0.001	0.389	0.531	0.079	0	0.002	0.377	0.491	0.130	0
13		0.328	0.570	0.102	0		0.318	0.531	0.151	0
19		0.252	0.609	0.139	0		0.246	0.569	0.185	0
28		0.170	0.632	0.198	0		0.167	0.592	0.241	0
41		0.097	0.619	0.284	0		0.095	0.584	0.321	0
60		0.043	0.555	0.402	0		0.041	0.526	0.433	0
88		0.013	0.439	0.548	0		0.012	0.416	0.572	0
129		0.002	0.294	0.704	0		0.002	0.278	0.720	0
189		0.001	0.157	0.842	0			0.149	0.851	0

TABLE 7  
Cumulative Mass-Chain Yields of Fission Products  
(Values are in percent of fissions)

Mass Number	U <sup>235</sup>		U <sup>238</sup>		Pu <sup>239</sup>	
	Thermal Neutrons*	Fission Neutrons	Fission Neutrons	8-Mev Neutrons	Thermal Neutrons	Fission Neutrons
72	$1.6 \times 10^{-5}$	$4.6 \times 10^{-4}$	$5.0 \times 10^{-6}$	-	$1.2 \times 10^{-4}$ *	-
73	$1.1 \times 10^{-4}$	0.0012	$3.7 \times 10^{-5}$	-	$2.2 \times 10^{-4}$	-
74	$(3.2 \times 10^{-4})^a$	0.0034	$1.1 \times 10^{-4}$	0.001	$4.1 \times 10^{-4}$	0.0011
75	$(8.8 \times 10^{-4})$	0.0062	$8.3 \times 10^{-4}$	0.0040	$7.5 \times 10^{-4}$	0.0023
76	(0.0029)	0.012	0.0012	0.0078	0.0014	0.0051
77	0.0083	0.023	0.0038*	0.014	0.0026	0.011
78	0.021	0.048	0.0095	0.026	0.0049	0.025
79	(0.041)	0.096	0.019	0.053	0.0090	0.043
80	(0.077)	0.19	0.045	0.096	0.016	0.075
81	0.14	0.21	0.088	0.18	0.030	0.14
82	(0.29)	0.50	0.20	0.35	0.056	0.23
83	0.544	0.80	0.40*	0.66	0.10	0.37
84	1.00	1.3	0.85*	1.02	0.17	0.60
85	1.30	1.85	0.80	1.45	0.28	0.92
86	2.02	2.5	1.38*	1.9	0.45	1.15
87	(2.94)	3.3	1.90	2.25	0.73	1.5
88	(3.92)	4.2	2.45	2.7	1.2	1.9
89	4.79	5.1	2.9*	3.17	1.9*	2.4

Continued

\*Seymour Katcoff, Fission-Product Yields From U, Th and Pu, Nucleonics, Vol. 16, No. 4, p. 78-85 (1958).

\*\*L.R. Bunney, E.M. Scadden, J.O. Abriam and N.E. Ballou, Radiochemical Studies of the Fast Neutron Fission of U<sup>235</sup> and U<sup>238</sup>, Second UN International Conference on the Peaceful Uses of Atomic Energy, A/Conf. 15/P/643, USA, June 1958.

\*\*\*G.P. Ford, J.S. Gilmore, et al, Fission Yields, LADC-3083.

\*\*\*\*L.R. Bunney, E.M. Scadden, J.O. Abriam, N.E. Ballou, Fission Yields in Neutron Fission of Pu<sup>239</sup>, USNRDL-TR-268, 1958, Uncl.

- a. Parentheses indicate estimated values or where Katcoff's value was altered in order to adjust the yields to a gross sum of 100 in each peak.
- b. Line indicates division of two peaks that was used for individual peak sums.

TABLE 7 (Cont'd)

Cumulative Mass-Chain Yields of Fission Products  
(Values are in percent of fissions)

Mass Number	U <sup>235</sup>		U <sup>238</sup>		Pu <sup>239</sup>	
	Thermal Neutrons*	Fission Neutrons	Fission Neutrons	8-Mev Neutrons	Thermal Neutrons	Fission Neutrons
90	5.77	5.8	3.2*	3.7	2.4	3.0
91	5.84	5.85	3.6	4.3	3.0	3.7
92	6.03	6.0	4.1	4.8	3.7	4.4
93	6.45	6.4	4.85	5.2	4.6	5.0
94	6.40	6.4	5.3	5.45	5.5	5.4
95	6.27	6.3	5.7*	5.6	5.9*	5.6
96	6.33	6.3	5.8	5.7	5.7	5.3
97	6.09	6.1	5.7	5.64	5.6*	5.2*
98	5.78	5.8	5.7	5.6	5.4	5.4
99	6.06	6.1**	6.3*	6.2**	5.9*	5.9*
100	6.30	6.7	6.1	6.4	6.0	6.4
101	5.0	5.3	5.5	6.5	6.0	5.9
102	4.1	2.9	5.6	5.9	5.9	5.3
103	3.0	1.7	6.6	5.0	5.8*	4.6
104	1.8	0.95	5.4	3.2	5.0	3.5
105	0.90	0.54	3.9	2.2	3.9*	3.2
106	0.38	0.30	2.7*	1.5	5.0*	3.6
107	0.19	0.17	1.35	1.0	4.0	3.1
108	(0.085)	0.095	0.67	0.70	3.0	2.6
109	(0.039)	0.053***	0.32*	0.48	1.5*	1.9*
110	(0.020)	0.030	0.15	0.33	0.65	0.81
111	(0.015)	0.022***	0.073*	0.23***	0.27*	0.34
112	(0.013)	0.020***	0.046*	0.19	0.10*	0.14*
113	(0.012)	0.018	0.043	0.17	0.055	0.090
114	(0.011)	0.017	0.041	0.16	0.046	0.075
115	0.0104	0.017***	0.040*	0.15***	0.041*	0.069*
116	(0.010) <sup>b</sup>	0.017 <sup>b</sup>	0.039	0.14	0.039	0.065
117	(0.010)	0.017	0.039	0.14 <sup>b</sup>	0.038	0.064
118	(0.010)	0.017	0.040 <sup>b</sup>	0.14	0.038 <sup>b</sup>	0.064 <sup>b</sup>
119	(0.011)	0.017	0.041	0.14	0.039	0.064

Continued

TABLE 7 (Cont'd)

Cumulative Mass-Chain Yields of Fission Products  
(Values are in percent of fissions)

Mass Number	U <sup>235</sup>		U <sup>238</sup>		Pu <sup>239</sup>	
	Thermal Neutrons*	Fission Neutrons	Fission Neutrons	8 Mev Neutrons	Thermal Neutrons	Fission Neutrons
120	(0.011)	0.018	0.042	0.15	0.041	0.065
121	(0.012)	0.020	0.044	0.16	0.044*	0.066
122	(0.013)	0.022	0.046	0.17	0.047	0.069
123	(0.015)	0.030	0.050	0.19	0.052	0.076
124	(0.017)	0.053	0.055	0.23	0.058	0.082
125	0.021	0.095	0.072	0.33	0.072*	0.14
126	(0.058)	0.17	0.175	0.48	0.175	0.35
127	(0.145)	0.30	0.39	0.70	0.39*	0.80
128	0.37	0.54	0.77	1.0	0.77	1.9
129	0.90	0.95	1.45	1.5	1.45	2.5
130	2.0	1.7	2.5	2.2	2.5	3.2
131	(2.88)	2.9	3.2*	3.2	3.8*	3.8
132	(4.31)	4.3	4.7*	4.4	5.0	4.6
133	(6.48)	6.1	5.5*	5.4	5.27*	4.9
134	(7.80)	7.3	6.6*	6.5	5.69*	5.2
135	(6.40)	6.3	6.0*	5.9	5.53*	5.1
136	(6.36)	6.4	5.9*	5.8	5.06*	5.3
137	(6.05)	6.0	6.2	5.85	5.24*	6.4*
138	5.74	5.7	6.4	5.9	5.5	5.4
139	(6.34)	6.4	6.5	6.0	5.7*	5.2
140	6.44	6.4	5.7*	5.6	5.68*	5.0*
141	(6.30)	6.3	5.7	5.5	5.2*	4.7
142	(5.85)	5.9	5.7	5.4	6.69*	4.9
143	(5.87)	5.8	5.5	4.97	5.4*	5.0
144	5.67	5.1**	4.9*	4.3**	5.29*	4.8
145	3.95	4.2	3.7	3.7	4.24*	4.4
146	3.07	3.3	3.1	3.17	3.53*	3.7
147	2.38	2.5**	2.6**	2.7**	2.92*	3.0
148	1.70	1.85	2.0	2.27	2.28*	2.36
149	1.13	1.3**	1.45	1.9**	1.75	1.86

Continued

TABLE 7 (Cont'd)

Cumulative Mass-Chain Yields of Fission Products  
(Values are in percent of fissions)

Mass Number	U <sup>235</sup>		U <sup>238</sup>		Pu <sup>239</sup>	
	Thermal Neutrons*	Fission Neutrons	Fission Neutrons	8 Mev Neutrons	Thermal Neutrons	Fission Neutrons
150	0.67	0.80	1.05	1.45	1.38*	1.48
151	0.45	0.50	0.74	1.02	1.08	1.16
152	0.285	0.31	0.50	0.66	0.83*	0.92
153	0.15	0.19**	0.32	0.41**	0.52	0.60
154	0.077	0.096	0.19	0.25	0.32*	0.37
155	0.033	0.048	0.11	0.15	0.20	0.23
156	0.014	0.023**	0.066*	0.092**	0.12*	0.14
157	0.0078	0.012	0.034	0.057	0.064	0.075
158	0.002	0.0062	0.016	0.032	0.034	0.043
159	0.00107	0.0034**	0.0090**	0.017**	0.020****	0.025
160	3.5x10 <sup>-4</sup>	0.0012	0.0036	0.0085	0.0092	0.011
161	7.6x10 <sup>-5</sup>	4.6x10 <sup>-4</sup> **	9.4x10 <sup>-4</sup>	0.0044**	0.0038****	0.0051

\*Seymour Katcoff, Fission-Product Yields From U, Th and Pu, Nucleonics, Vol. 16, No. 4, p. 78-85 (1958).

\*\*L.R. Bunney, E.M. Scadden, J.O. Abriam and N.E. Ballou, Radiochemical Studies of the Fast Neutron Fission of U<sup>235</sup> and U<sup>238</sup>, Second UN International Conference on the Peaceful Uses of Atomic Energy, A/Conf. 15/P/643, USA, June 1958.

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- Parenttheses indicate estimated values or where Katcoff's value was altered in order to adjust the yields to a gross sum of 100 in each peak.
- Line indicates division of two peaks that was used for individual peak sums.

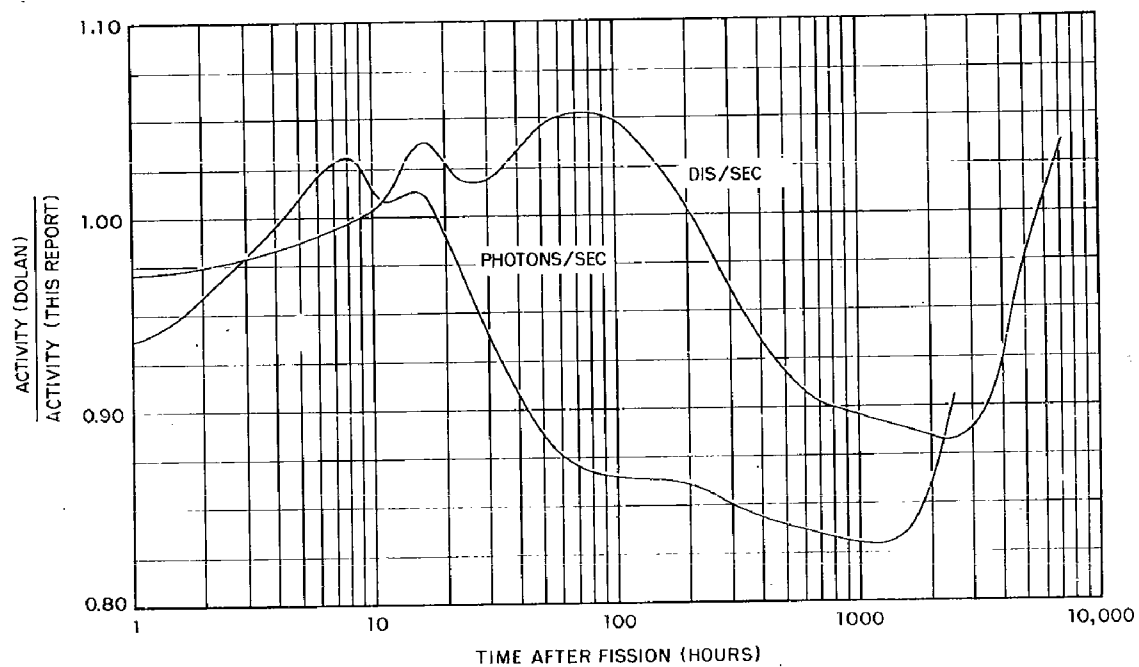


Fig. 3 Comparison of 14.0 Mev Neutron (Dolan<sup>29,30</sup>)  
to 8 Mev Neutron Fission of U<sup>238</sup>



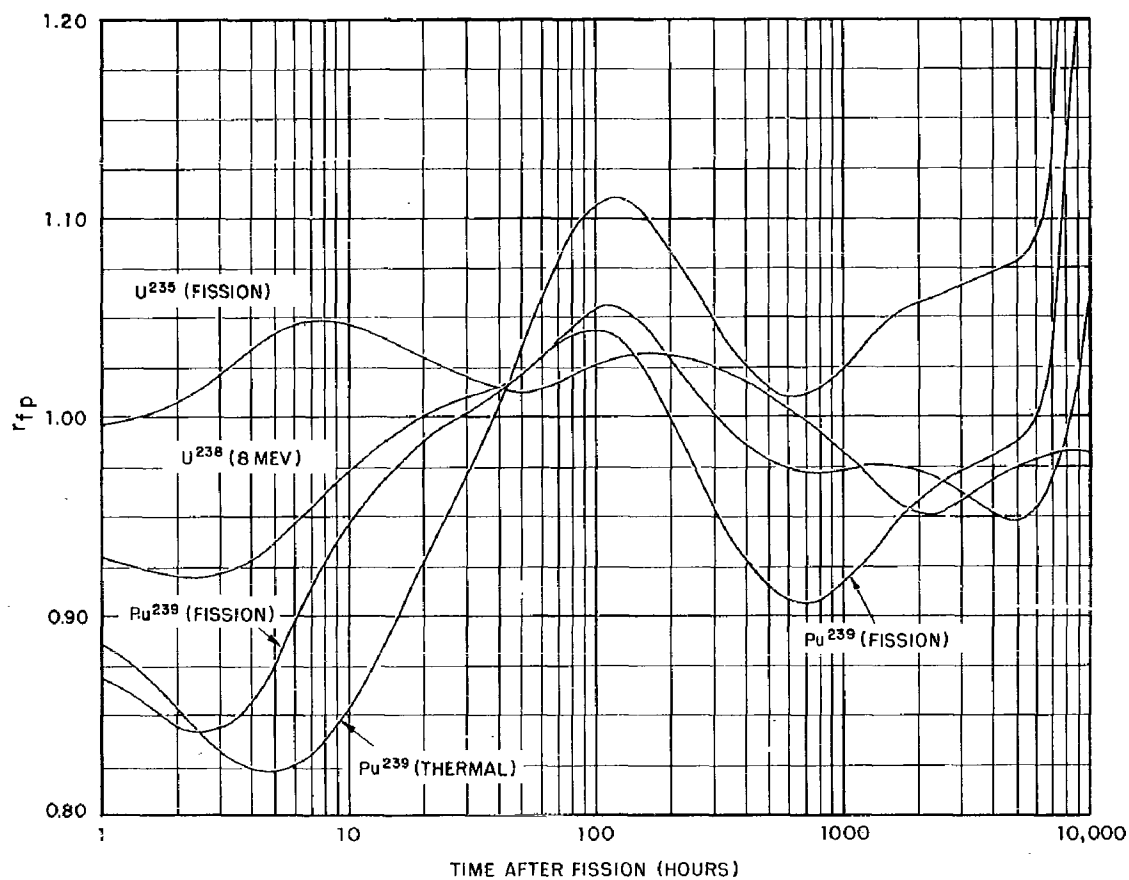


Fig. 4 Gross Air Ionization Rate "R" Factors for Various Types of Fission (hours after fission)

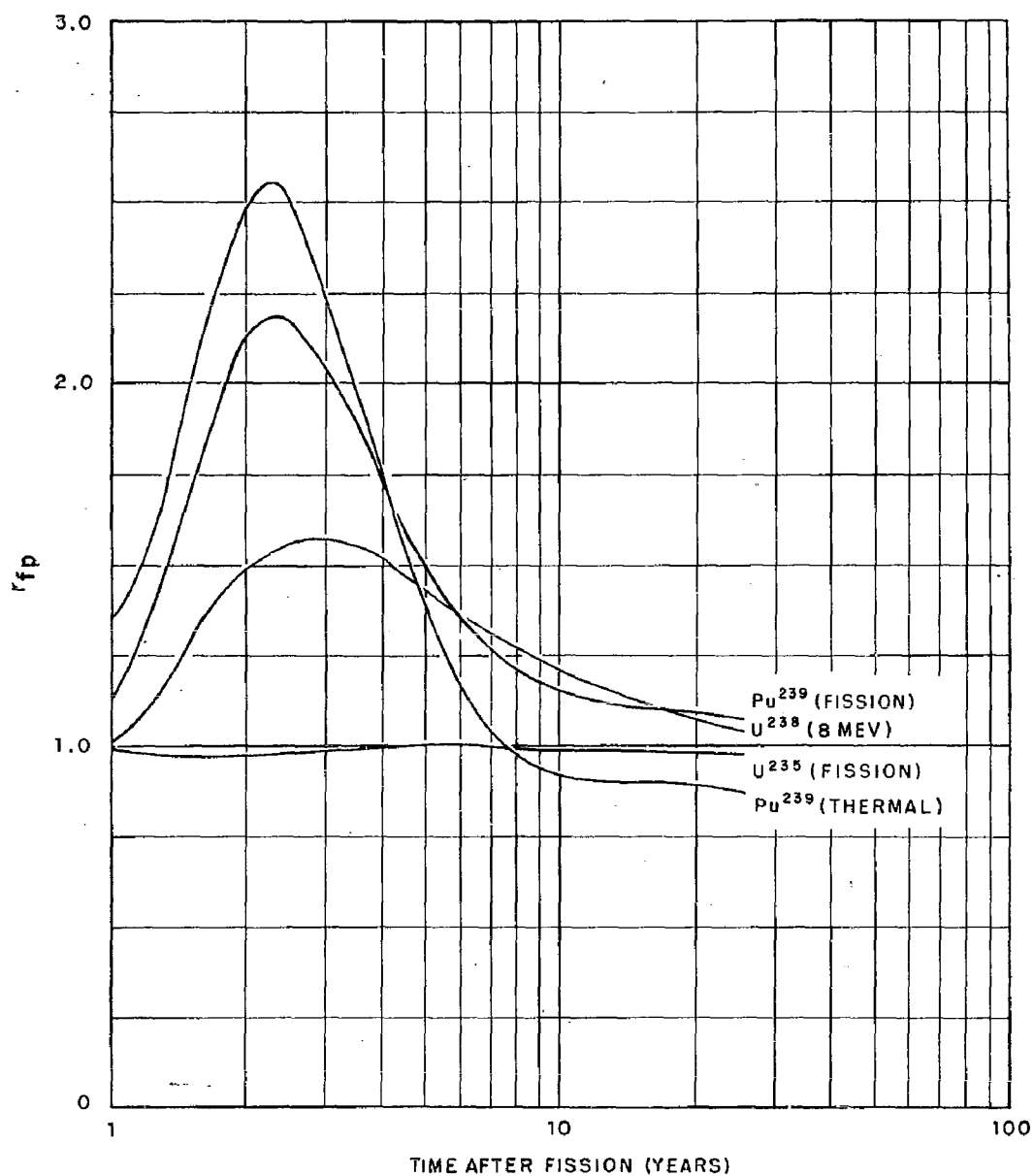
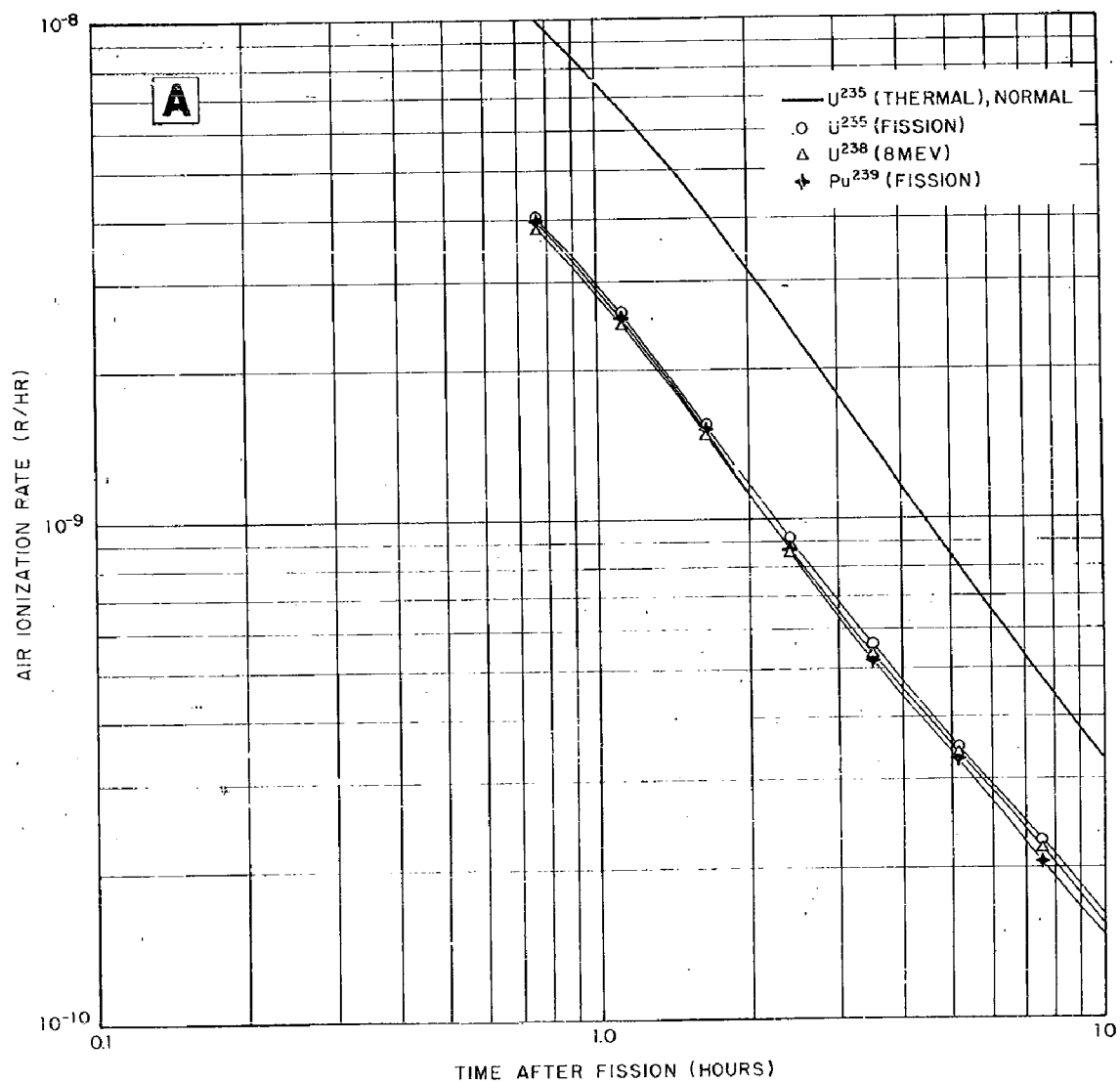
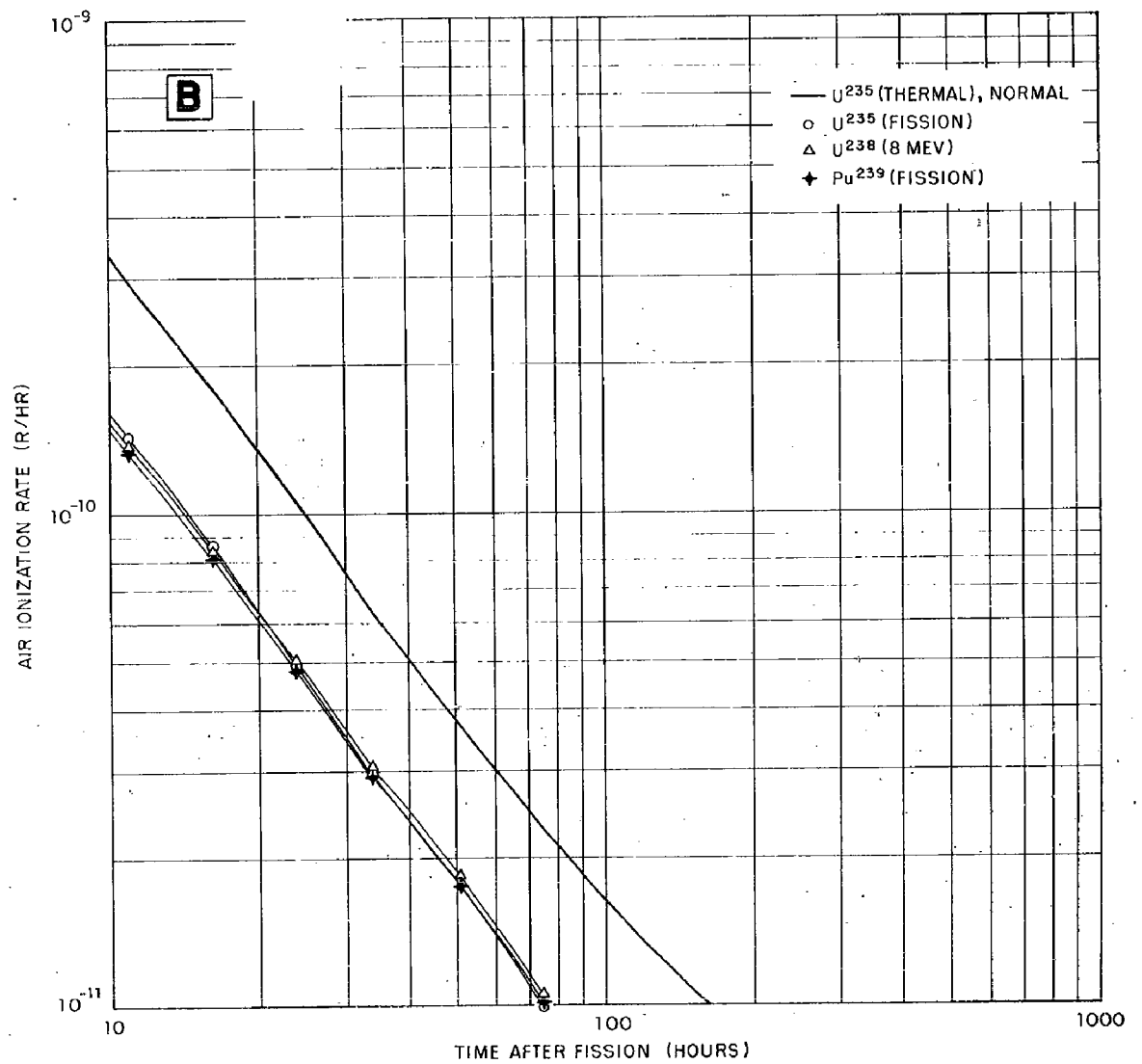


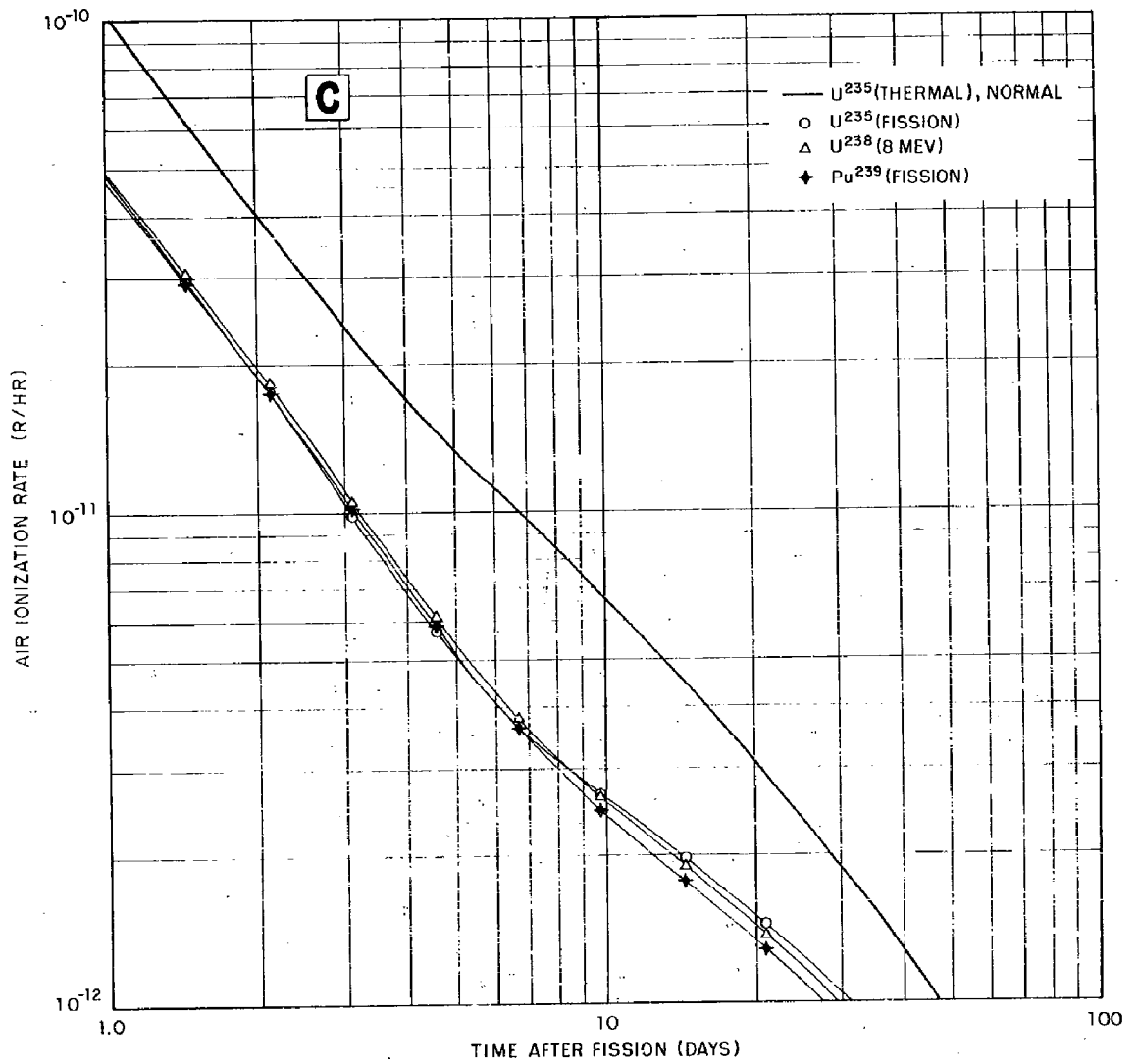
Fig. 5 Gross Air Ionization Rate "R" Factors for Various Types of Fission (years after fission)

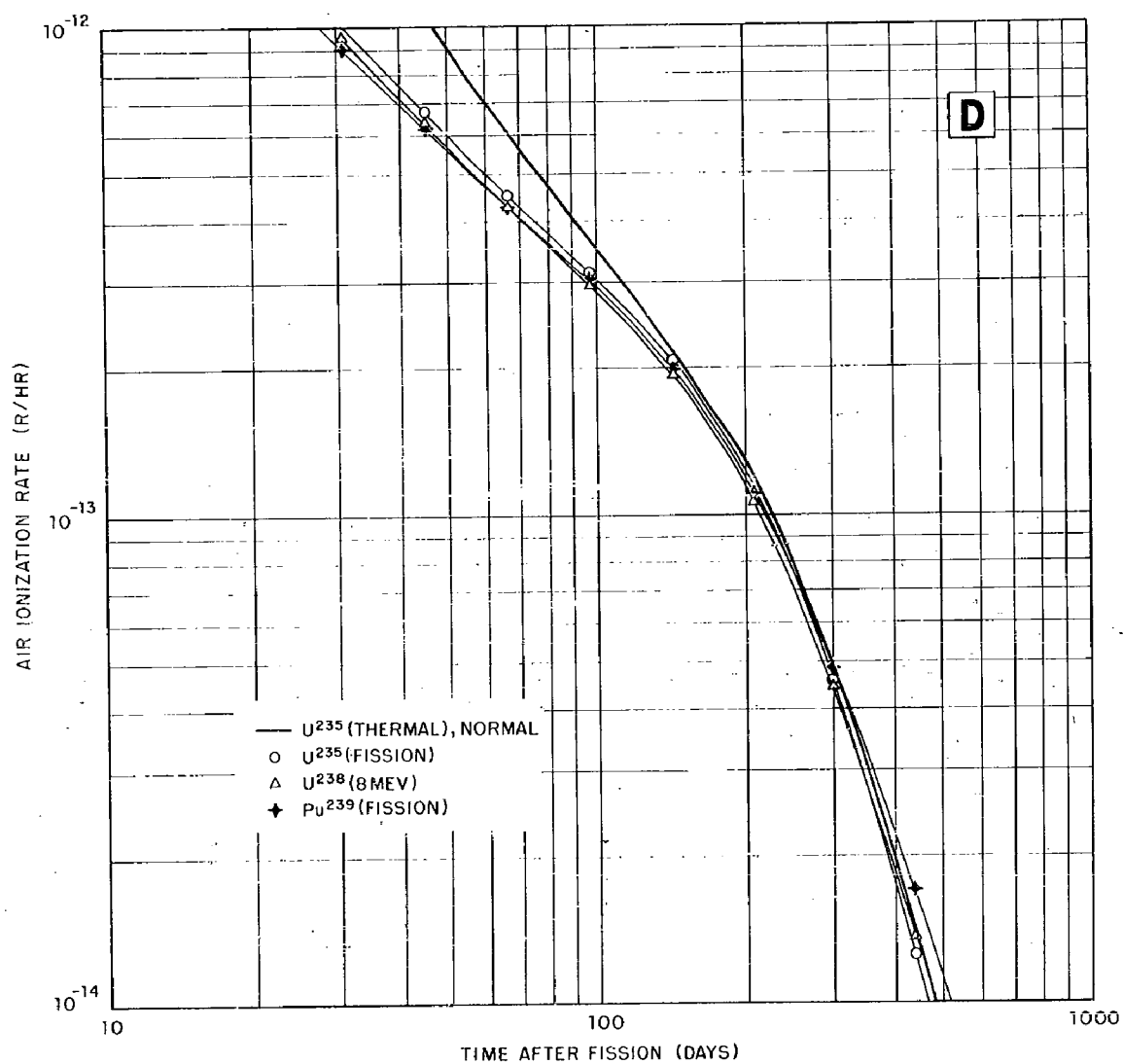
Fig. 6 Air Ionization Rate at 3 ft Above a Smooth Infinite Plane Uniformly Contaminated With Fractional Fission Products From  $10^4$  Fissions/sq ft, in Melted Fallout Particles From a 2.3 MT Yield Surface Detonation. Rates for normal fission products from thermal neutron fission of U235 are given for comparison.

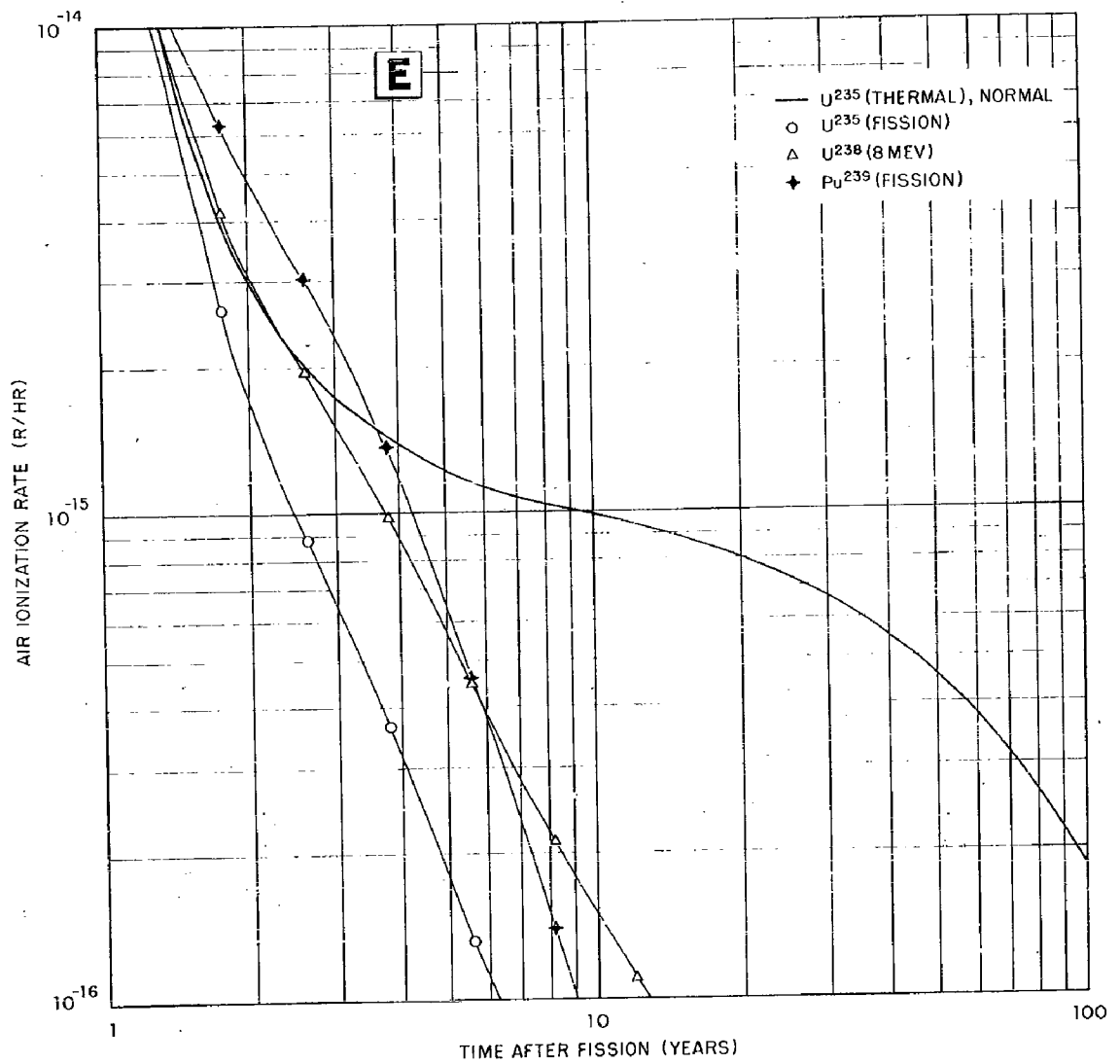
A,B. Hours after fission  
C,D. Days after fission  
E,F. Years after fission



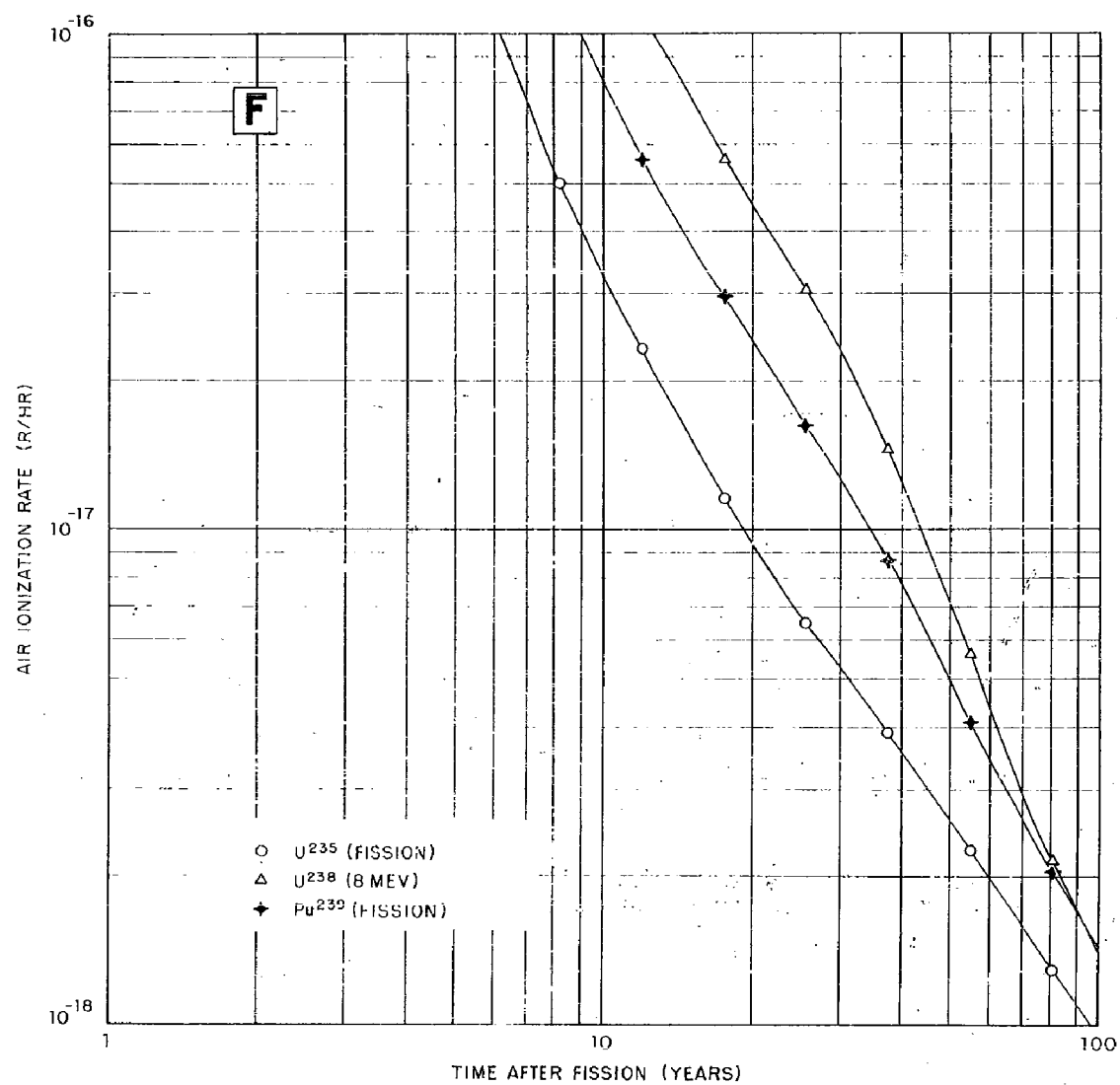












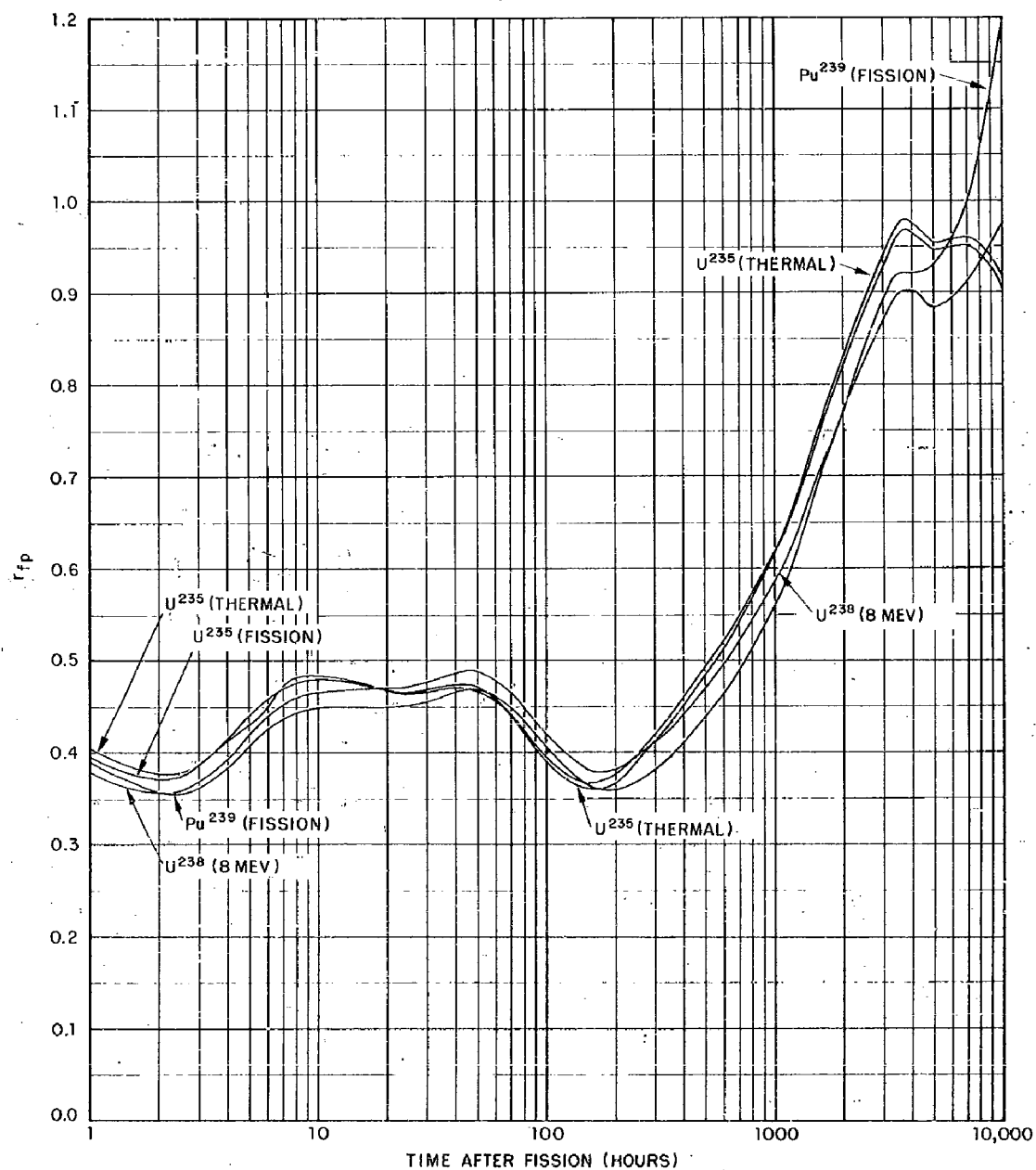


Fig. 7 Variation of the Gross Ionization Rate "R" Factor for the Fractionated Fission Products With Time After Fission

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